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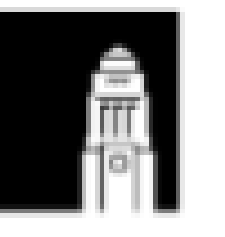
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# Modelling the uptake of domestic energy technologies via local networks and integrating real-world data



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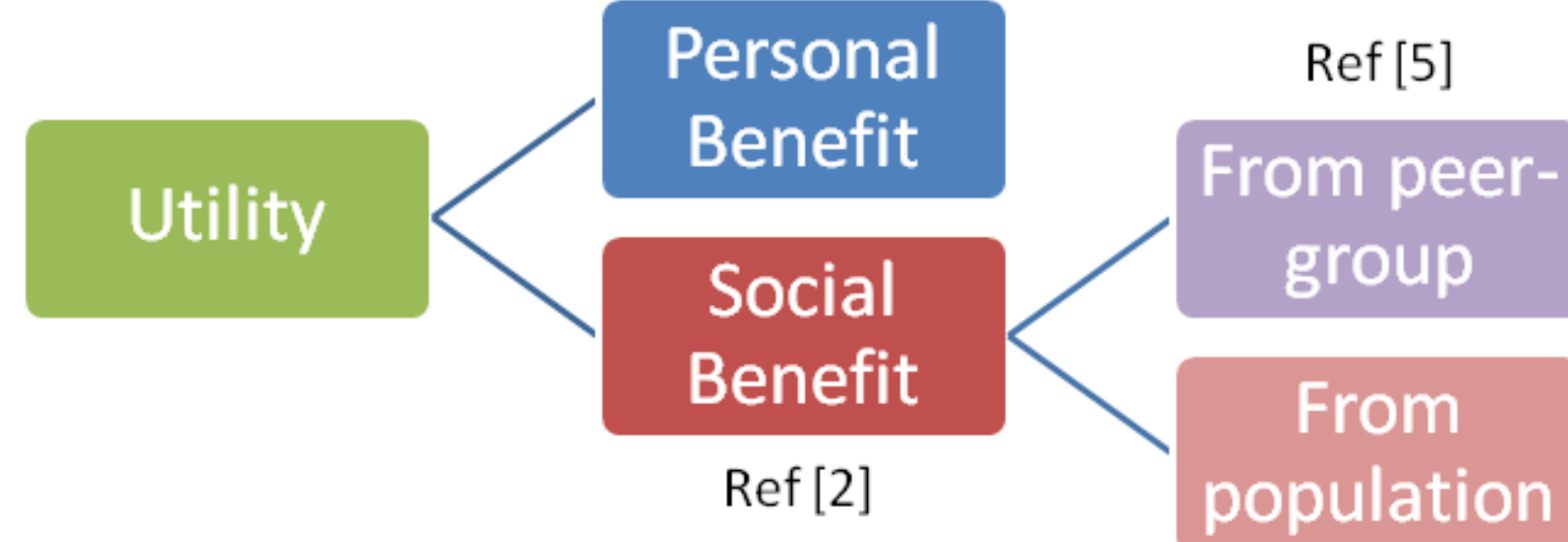
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## Introduction

- Companies and policy-makers are in a position to influence residents and businesses to adopt domestic energy measures and reduce energy demand;
- Tools are needed to support decision-makers in achieving their energy and climate change targets [1];
- Quantification and integration of real-world data into mathematical and simulation models is needed for them to be reliable and usable as tools by strategic planners.

## Modelling Uptake of Innovation

Householder decisions to adopt a particular innovation are based on a combination of factors:



Total Utility to household[3]:

$$u_i = \alpha_i p_i + \beta_i s_i + \gamma_i m,$$

$p_i, s_i, m$ : personal, peer-group and societal influence,  
 $\alpha_i, \beta_i, \gamma_i$ : relative weightings given to each factor.

- Households are represented as *nodes* on a network.
- People communicate via peer-to-peer interactions.
- Interactions represented by *links* between nodes.

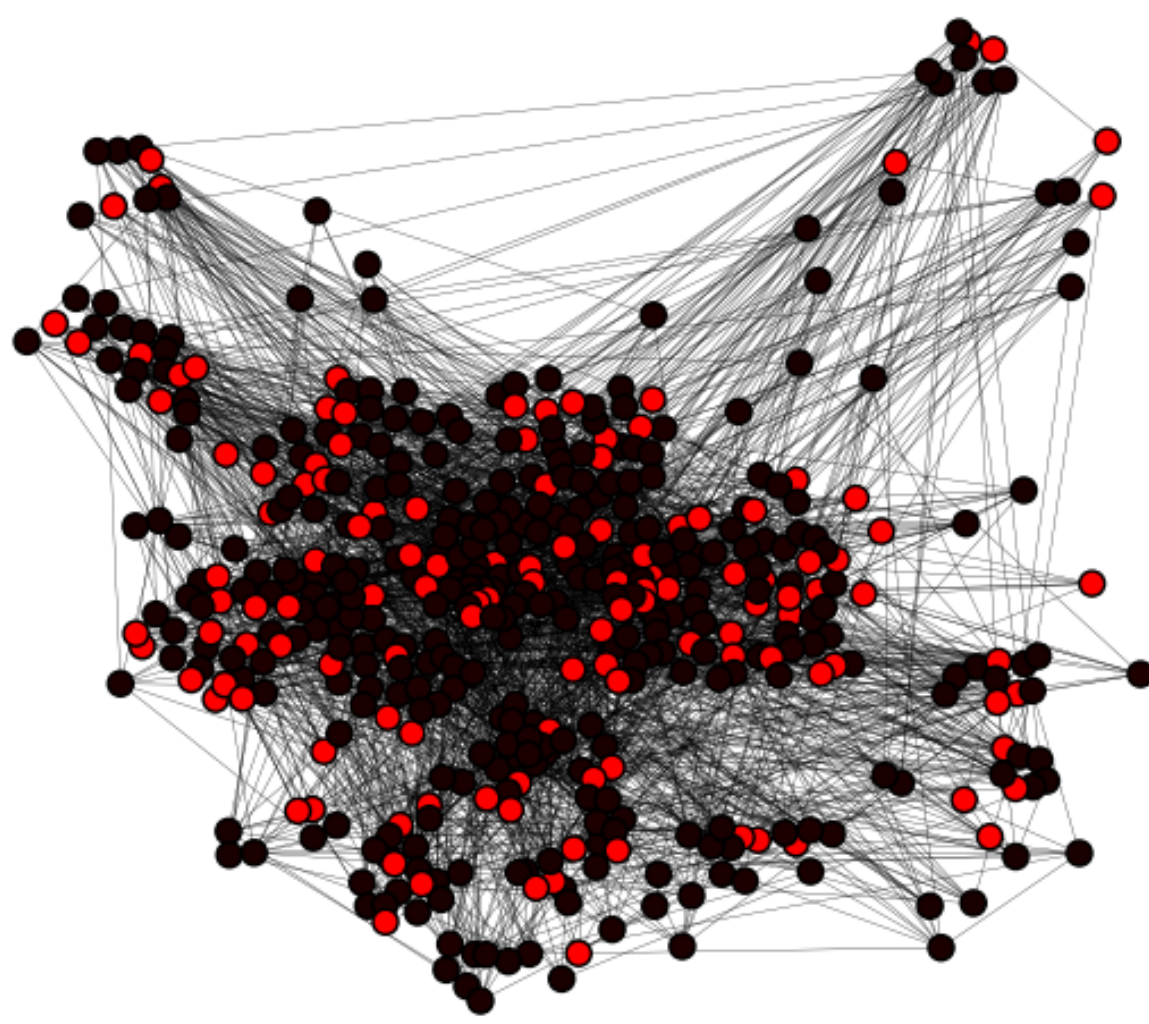


Figure 1: Network Model

- Each node  $i$  has adoption state variable  $x_i = 0, 1$ .
- Dynamical equations determine individual uptake.

Adoption Rule:

$$x'_i = \begin{cases} 1 & \text{if } x_i = 1, \\ 1 & \text{if } x_i = 0 \text{ and } u_i > \theta_i, \\ 0 & \text{otherwise.} \end{cases}$$

- $\theta_i$ : threshold (barriers, costs etc.),

## Modelling Social Networks

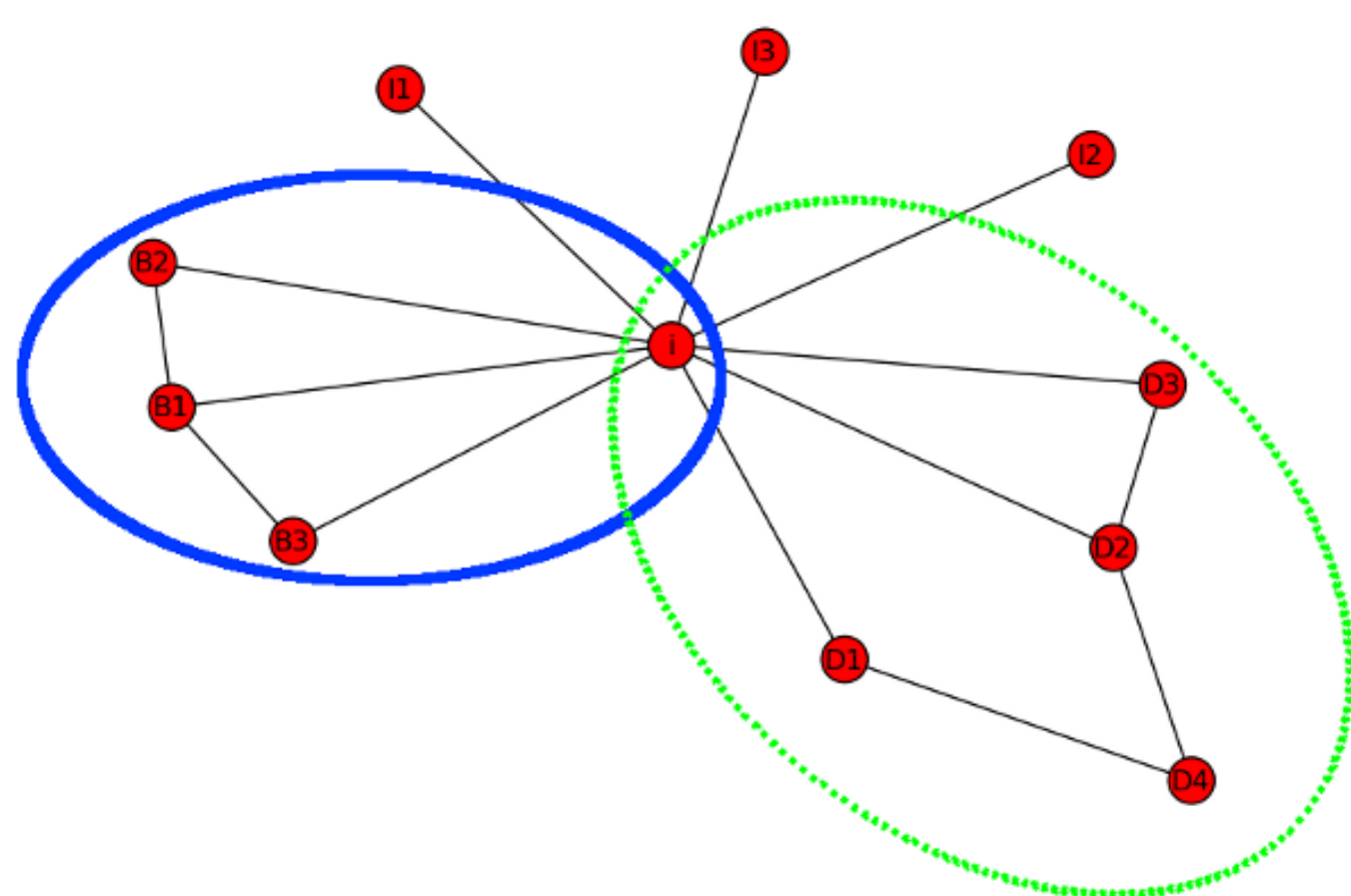


Figure 2: Links established between nodes either individually or via groups[4] — social, workplaces, etc. Here there are  $N = 11$  nodes, with node  $i$  connected to  $G = 2$  from a total of  $W$  groups overall. There are  $L = 3$  links established per group and individually.

## Integrating Real-World Data

- A survey of Leeds residents was undertaken in May–June 2011 in order to populate the model with empirical data.
- The survey gathered information about household type and tenure, socio-economic data, geographic location, and questions on who people spoke to (and therefore were connected with) specifically about energy-related issues.
- 1068 valid responses were received.
- The table below shows how empirical data from the survey has been used in the model.

Model Feature	Parameter	Data Source
Network structure	$N, G, M \mid W, L$	Survey   Assumption
Individual connections	$I \mid L$	Survey   Assumption
Group connections	$G \mid L$	Survey   Assumption
Archetypes	$A_i = (\alpha_i, \beta_i, \gamma_i), P(A_i)$	Simulation
Threshold	$\theta \mid P\theta$	Survey   Assumption

- Individual preferences and social network influences are important factors in the adoption of energy innovations; local authorities have the means to potentially harness these influences to their advantage in encouraging increased adoption.
- Since expected uptake of an innovation emerges as a result of adoption behaviour of individuals connected on a social network, in order for us to investigate potentially successful interventions, a complex-systems perspective is needed.

## Systematic Investigation of Parameters

Individual simulations *with the same parameters* can depend sensitively on model details and initial conditions:

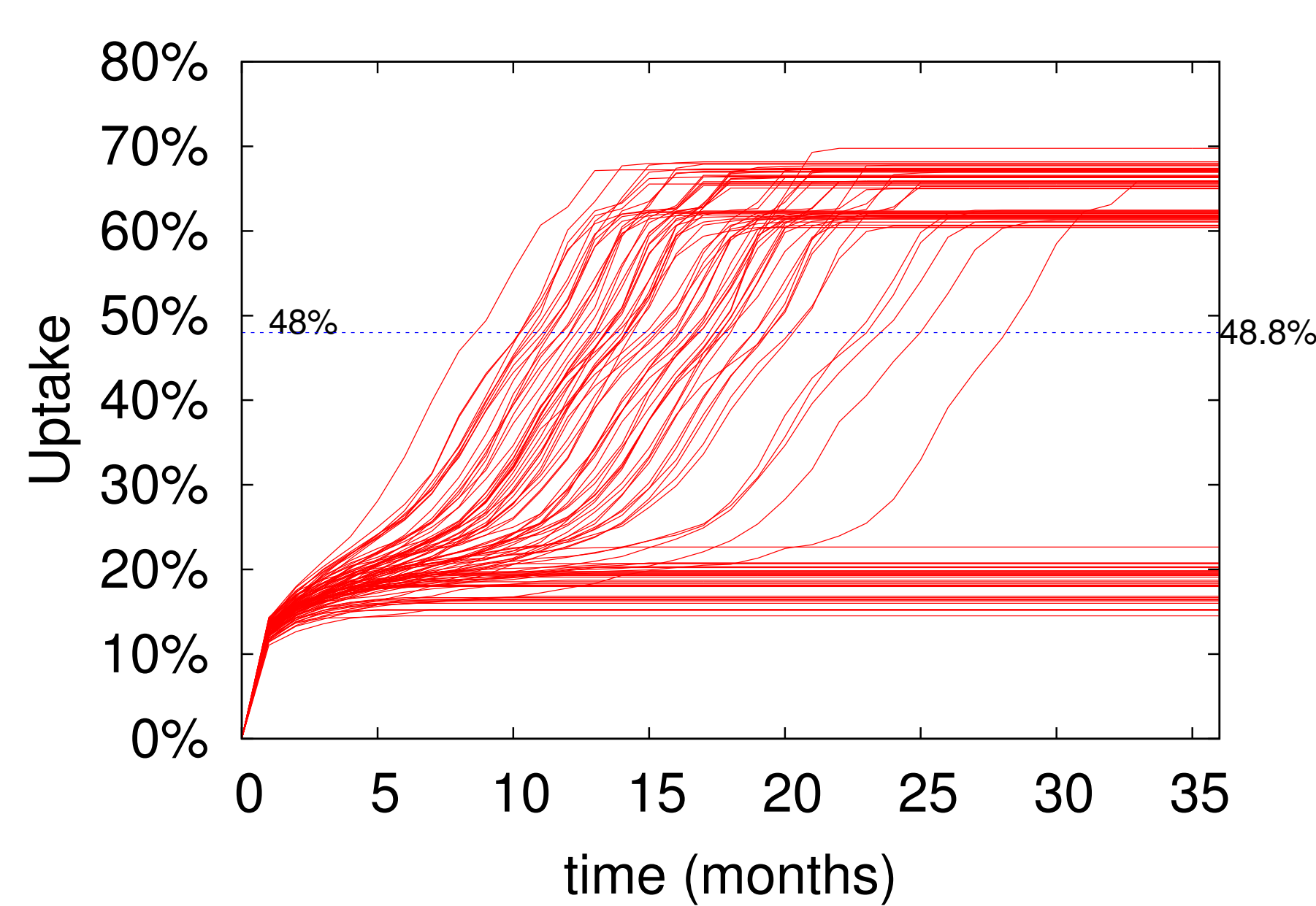


Figure 3: Examples of 100 individual runs with same parameters but different details and seed.

Need to look at *ensemble averages* over many realisations.

Method:

- pick a set of parameters,
- perform 20 runs for 36 time-steps,
- plot average uptake for that set of parameters,
- can study sensitivity to various parameters.

## Objectives

- To develop tools for modelling diffusion of energy technologies via networks of households, in order to aid decision-making in local authorities;
- To use real-world empirical data to guide the models towards more accurately representing heterogeneous populations and studying the effect this has on the model results.

## Results

A selection of results is shown here.

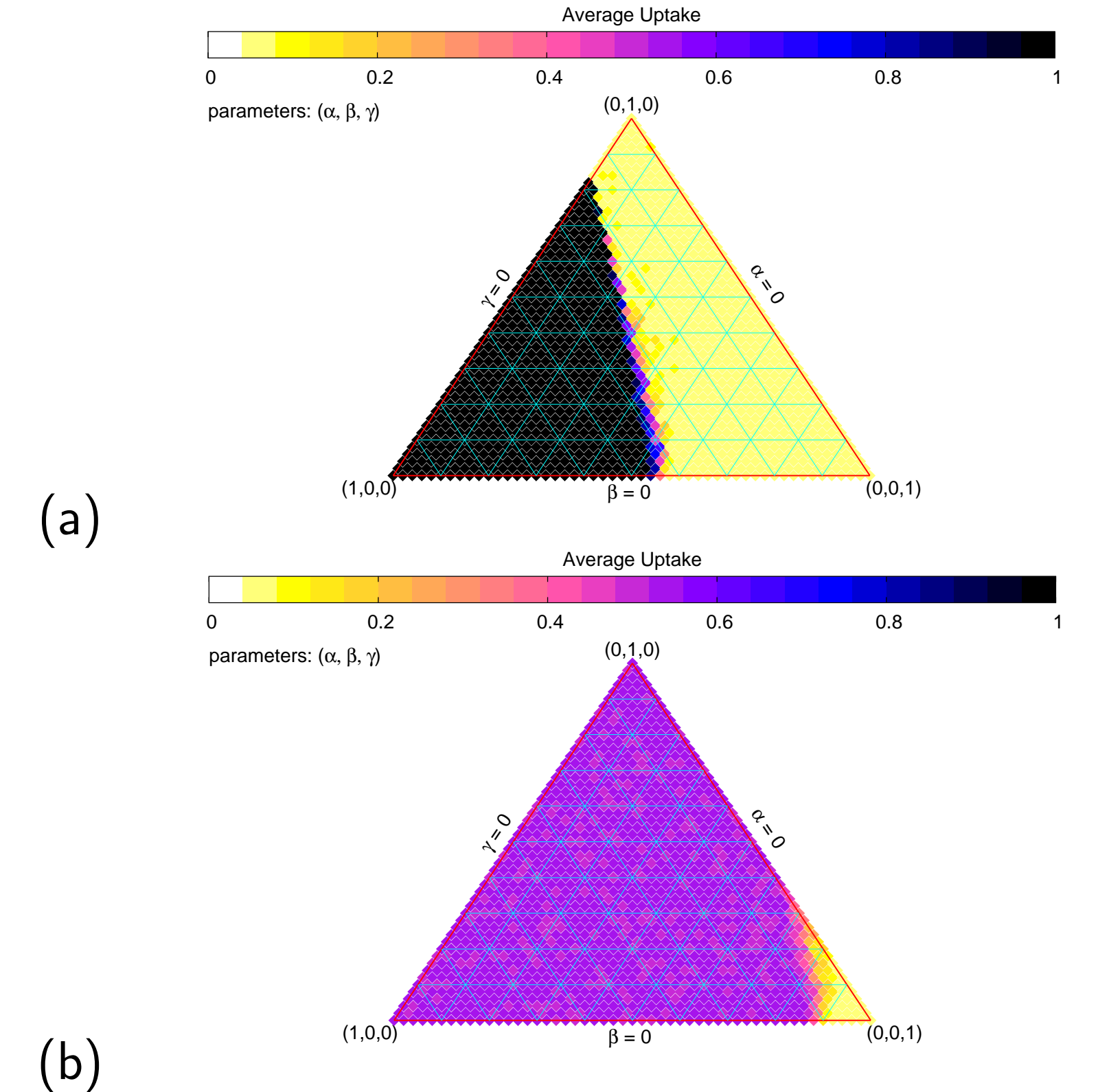


Figure 4: Different values of two thresholds, each assigned to half the nodes. (a)  $\theta_1 = 0.45, \theta_2 = 0.25$  (b)  $\theta_1 = 0.9, \theta_2 = 0.1$ . The shift in the behaviour demonstrates that the choice of thresholds is crucial to the outcome of the simulations.

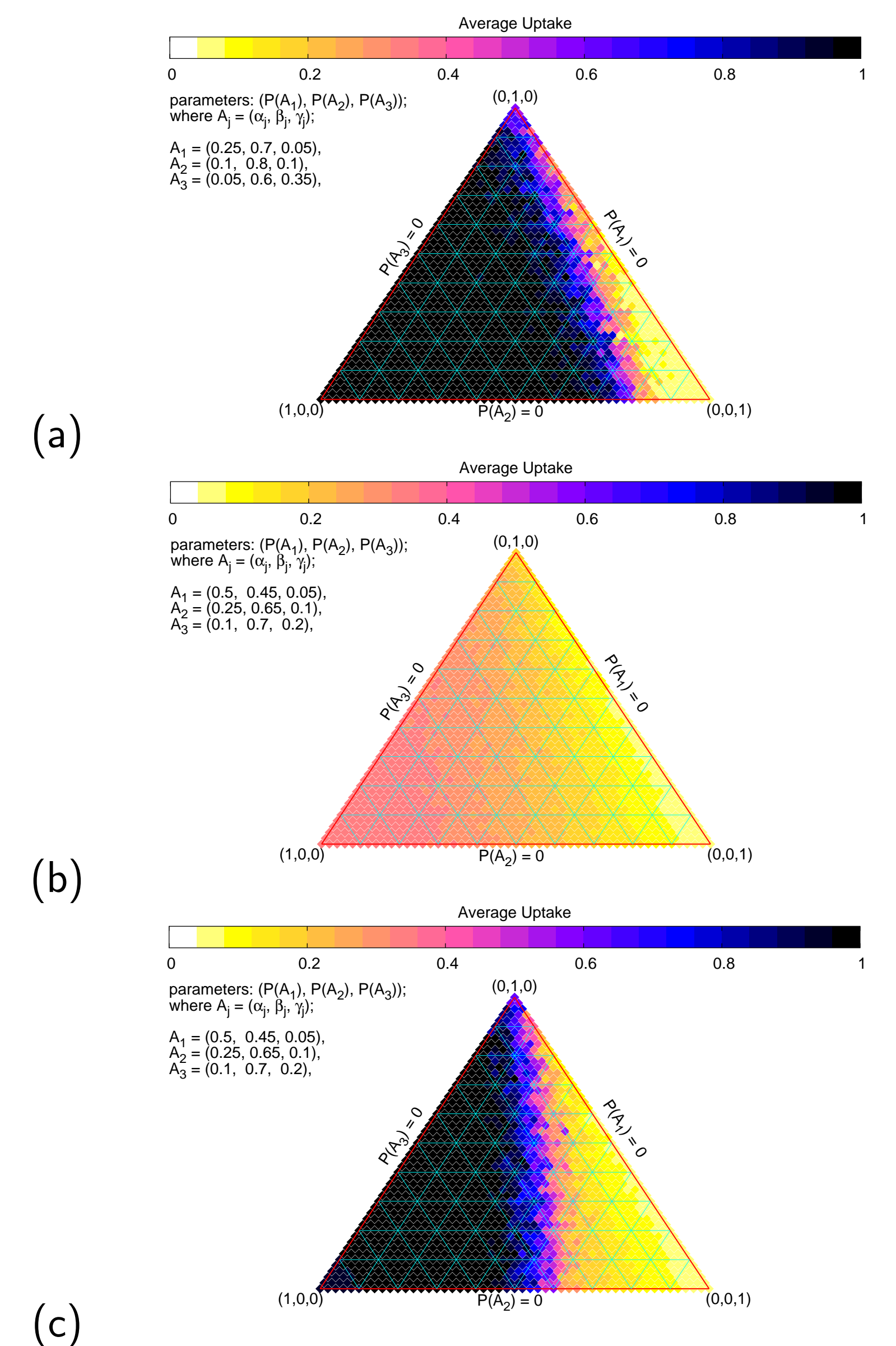


Figure 5: The population is divided into three archetypes  $A_j = (\alpha_j, \beta_j, \gamma_j)$ . Each point on the plot is for a different set of relative proportions of the population ( $P(A_1), P(A_2), P(A_3)$ ). (a) Single threshold  $\theta = 0.25$ . (b) Thresholds are distributed with  $\theta = (1, 0.75, 0.45, 0.25)$  with proportions (0.5, 0.05, 0.17, 28). (c) The  $\theta = 1$  threshold is lowered to  $\theta = 0.45$ . The difference between the results is due to the different distribution of archetypes and thresholds.

## Conclusions

- We have developed a model for exploring the parameter space to investigate what factors are important in the diffusion of innovations on a real-world social network.
- We extended our basic dynamical network model to integrate empirical data (gathered via a city-wide survey) into the models in order to more closely represents a real social system.
- We have highlighted the need for new data to understand (in a quantitative way) householder barriers and drivers to adoption of energy-efficient innovations.
- The benefits to adopting network interventions are becoming clearer and this is certainly an area where further research is warranted.

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